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Title: Axis 2 rf Observations

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# Axis 2 rf Observations

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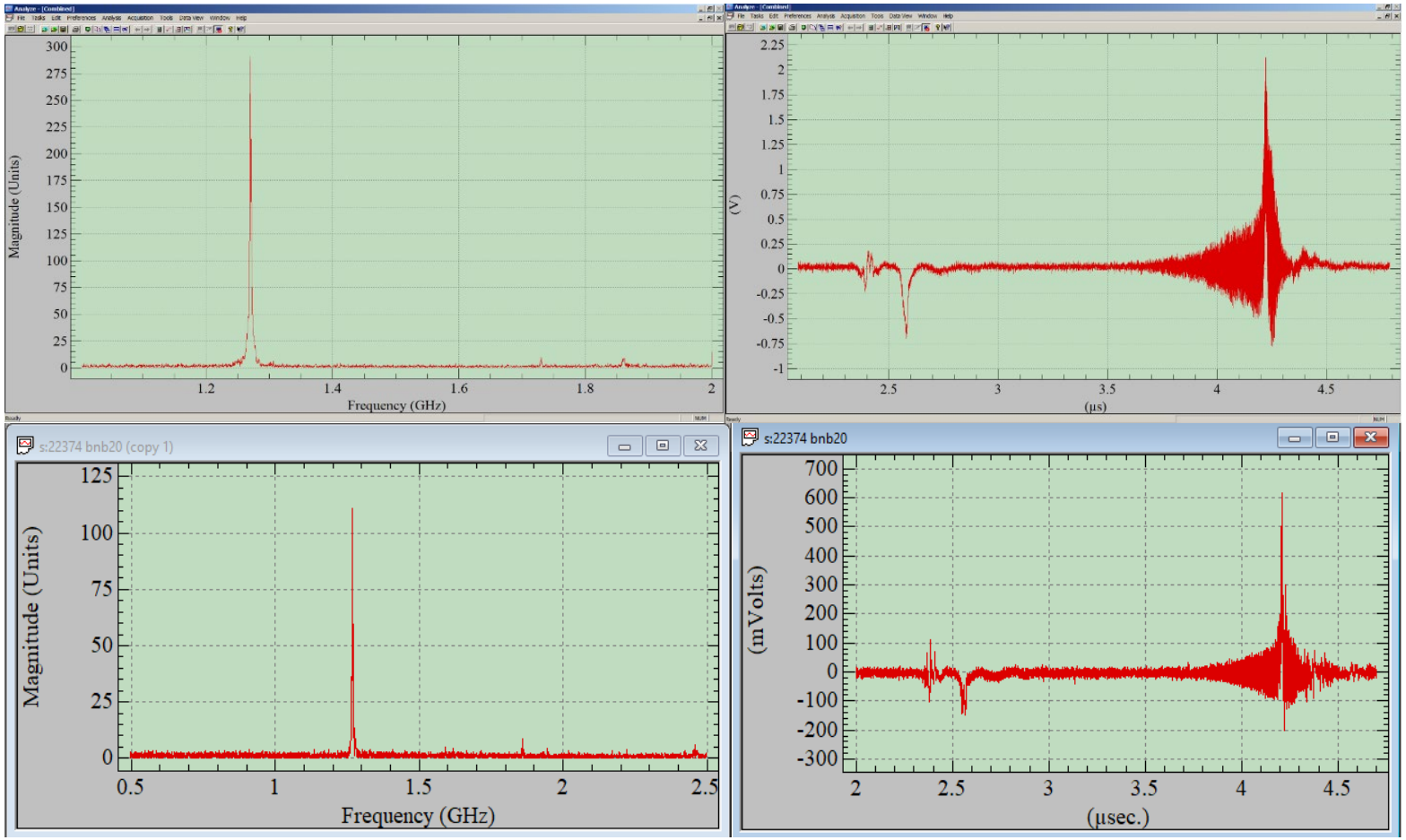
23-September-2020

# 2020 Review of Axis 2 rf

- Review of rf associated with septum dump
- Description of present rf
  - Not the same
- Historical review of rf for hydros since late 2014
  - Hydros presumably represent the best tune at a given time
  - Between May 2017 to March 2018 significant changes in the 1-2.5 GHz spectrum are observed
  - Accelerator configuration and potential causes are discussed
- rf associated with BBU is always present
  - Some evidence that this may contribute to the spot size on target is presented

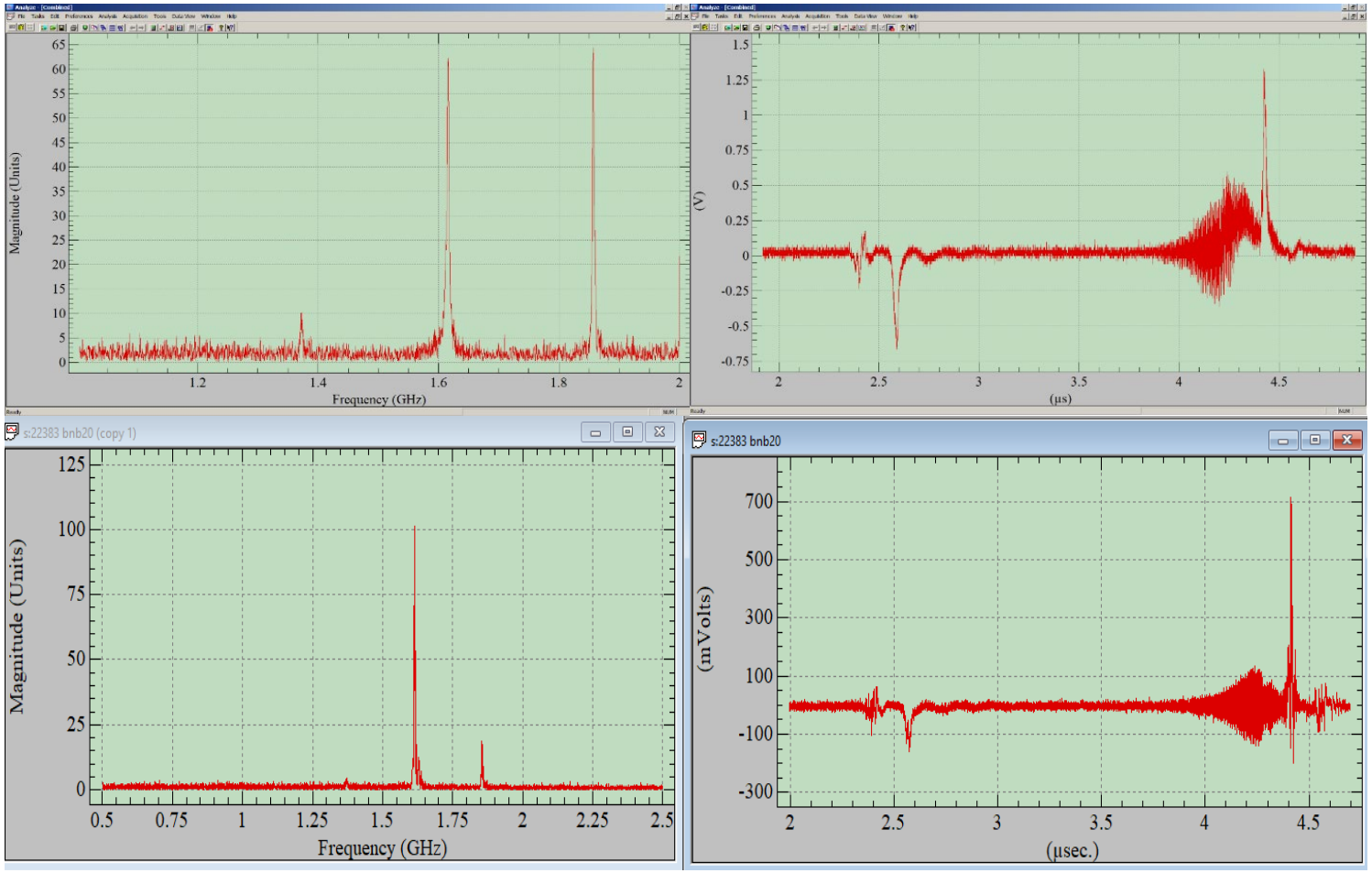
# Septum Dump rf




Shot 22374

Rf on kicker (top)
Rf on bnb20 bdot (bottom)
Spectrum on left
Raw signal on right

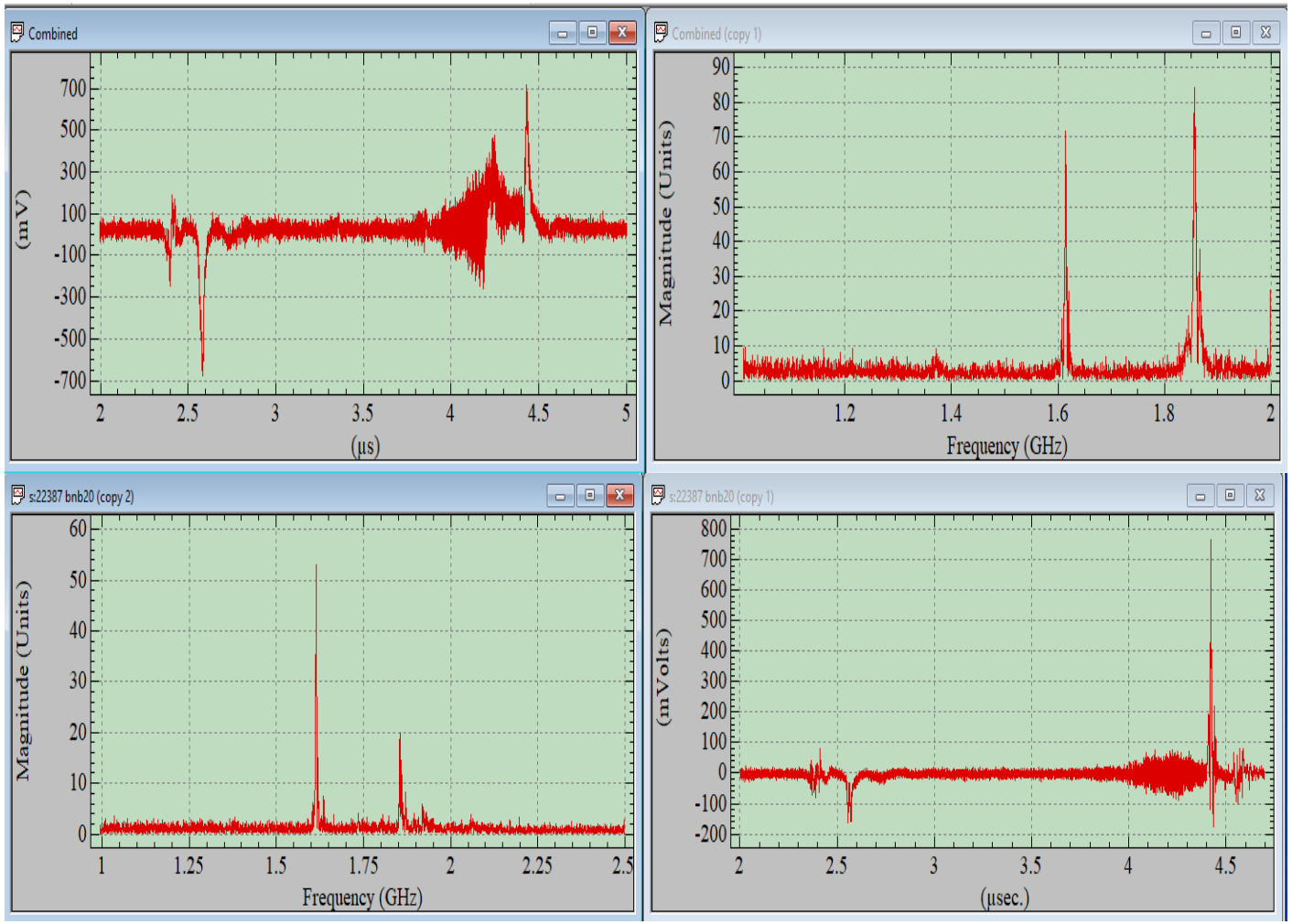
# Septum Dump rf




Shot 22383

Rf on kicker (top)
Rf on bnb20 bdot (bottom)
Spectrum on left
Raw signal on right

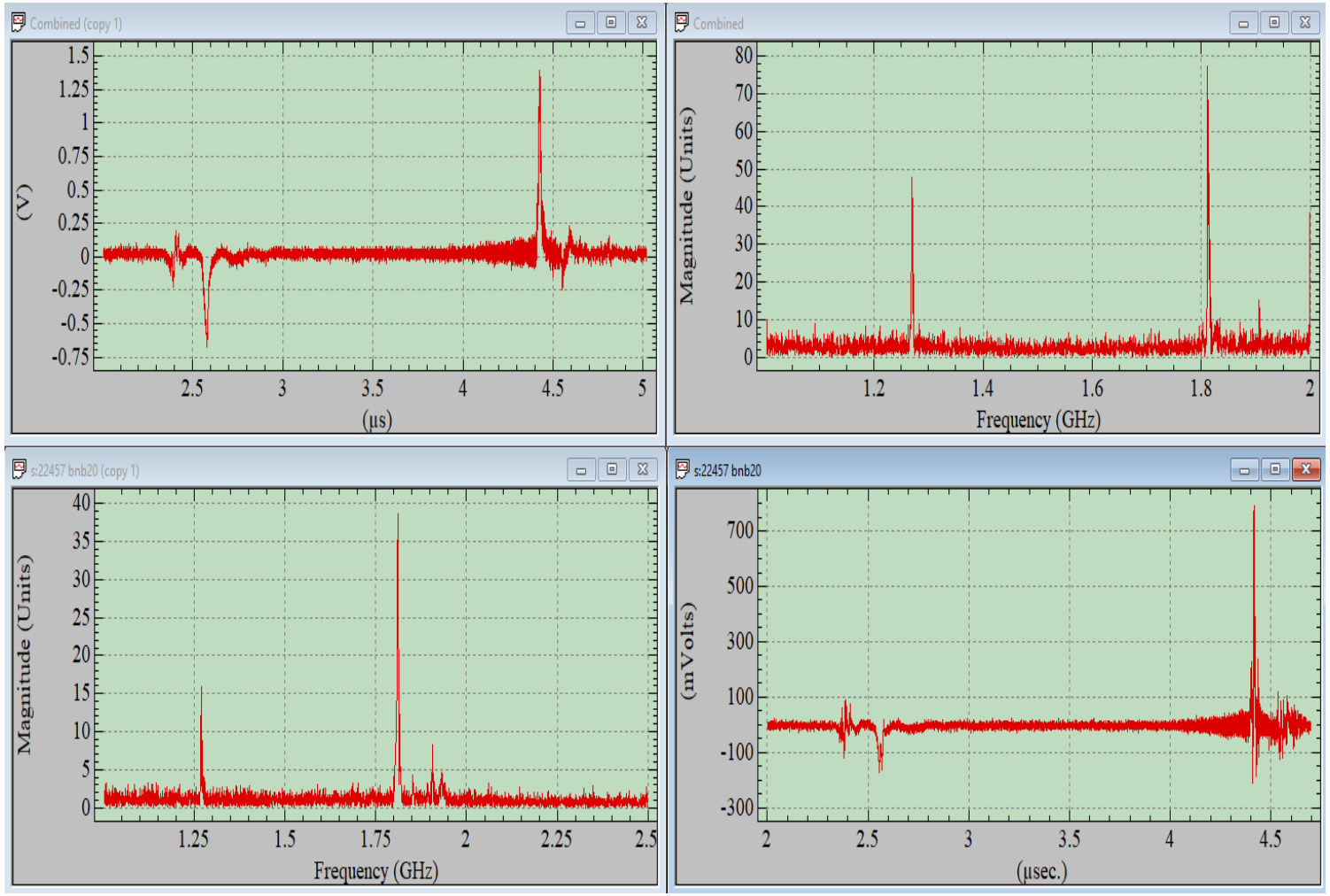
# Septum Dump rf




Shot 22387

Rf on kicker (top)
Rf on bnb20 bdot (bottom)
Spectrum on left
Raw signal on right

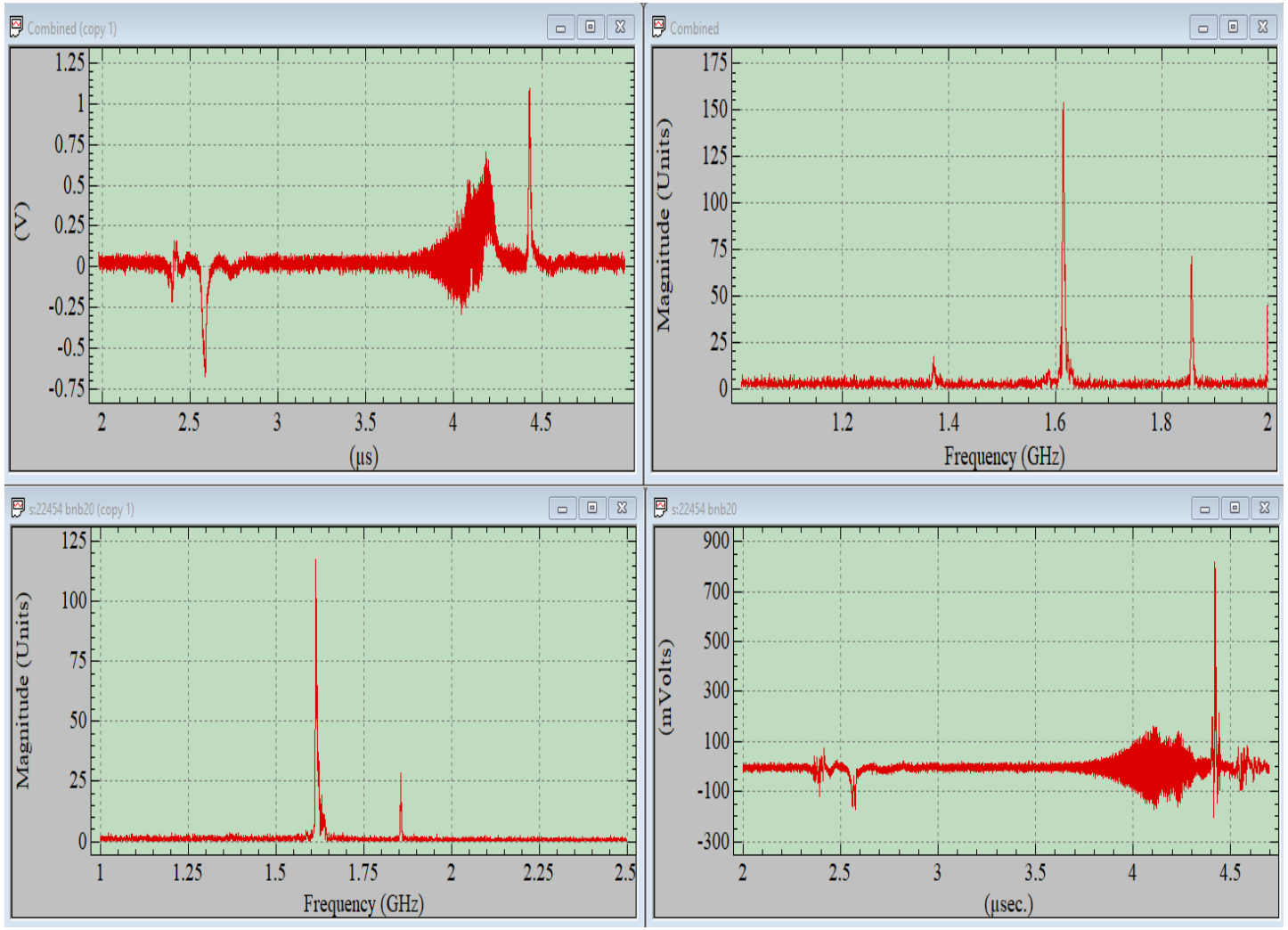
# Septum Dump rf




Shot 22457

Rf on kicker (top)
Rf on bnb20 bdot (bottom)
Spectrum on left
Raw signal on right

# Septum Dump rf



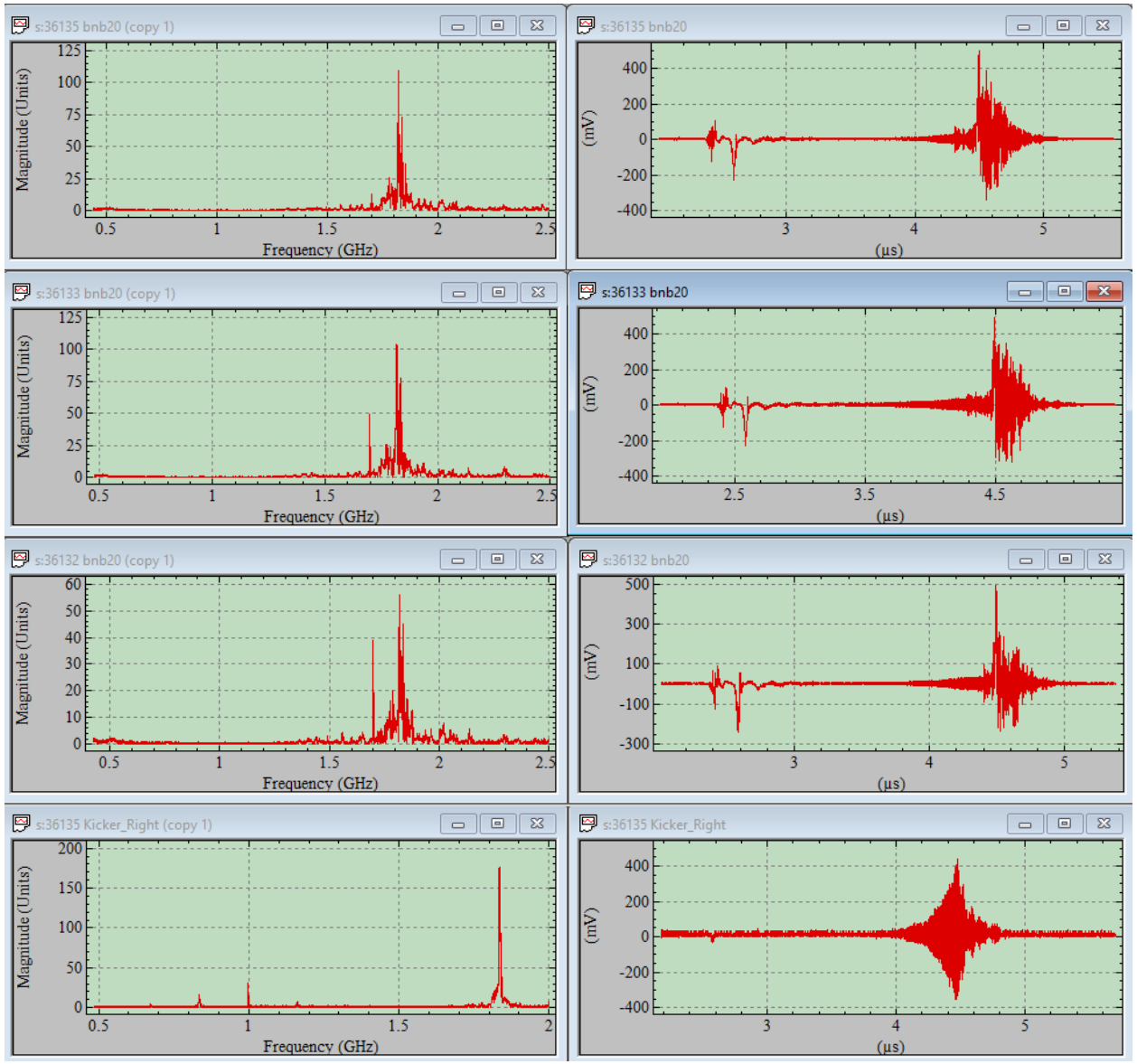

Shot 22454

Rf on kicker (top)
Rf on bnb20 bdot (bottom)
Spectrum on left
Raw signal on right

# Septum Dump rf

- The only difference in these five shots is the tune to the septum dump
  - Changes in trajectory excite different rf modes
- At early times ions are generated through stimulated desorption
- At later times, the beam size on the septum dump decreases due to beam neutralization by the backstreaming ions.
- The smaller beam sizes result in faster heating of the dump eventually creating a surface plasma from the desorbed water vapor on the surface.
- At higher temperatures the backstreaming ion current will transition from stimulated desorption to thermionic or space charge limited emission as described by Caporaso resulting in higher currents of more energetic ions.
- Since the momentum of the two beams is not identical the interaction of the electron beam and higher current backstreaming ions in a magnetic field (septum dipole) generates RF. The magnetic field separated the two trajectories and the attraction of the two beams causes oscillations.
- The location of the oscillations is affected by the trajectory.

# Present rf (Mode 1 operations on 8-20-20)




Three figures on top correspond to the bnb20 signal for three different shots with the spectrum on the left and the raw signal on the right.

The figure on the bottom is the right kicker electrode again with the spectrum on the left and the raw signal on the right.

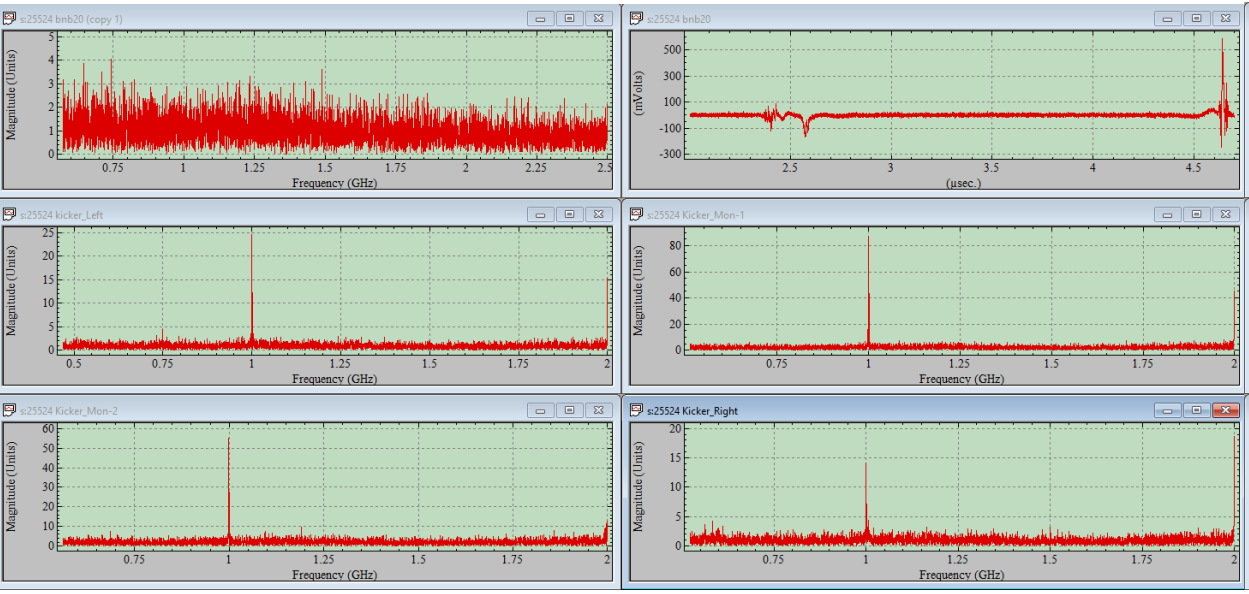
The dominant frequency in 1.84 GHz.

There is a vacuum burst correlated with the strength of the rf which typically trips off the kicker.

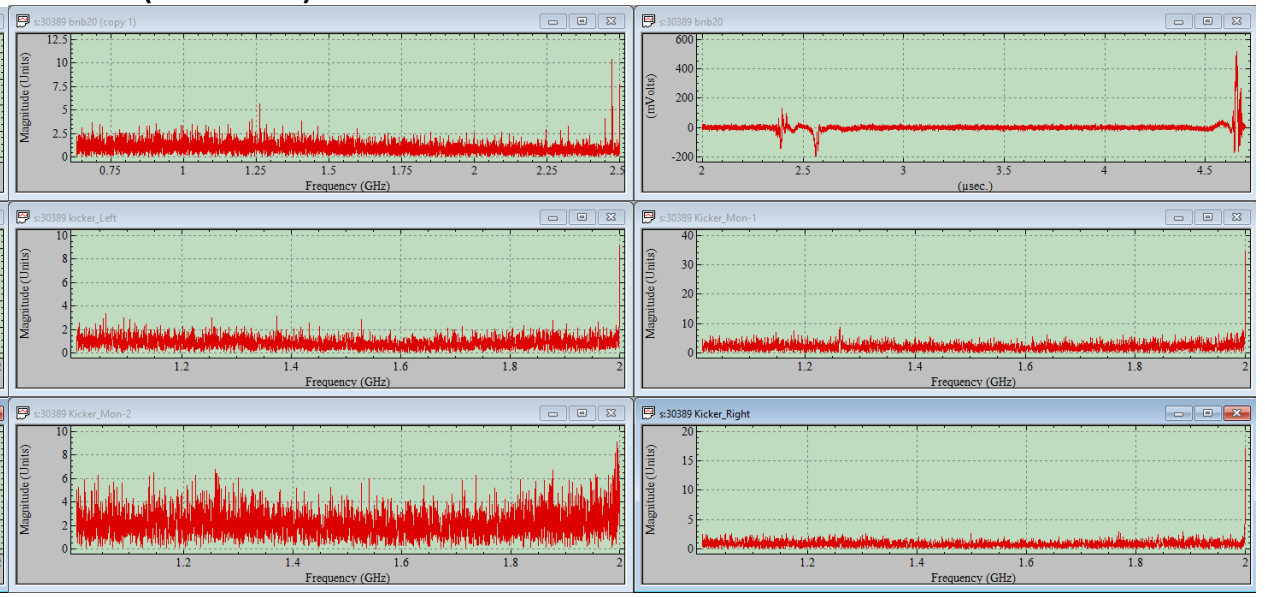
Significant beam motion is observed late in pulse 10-20% of time

# Historical rf on hydros (pre 5-17)

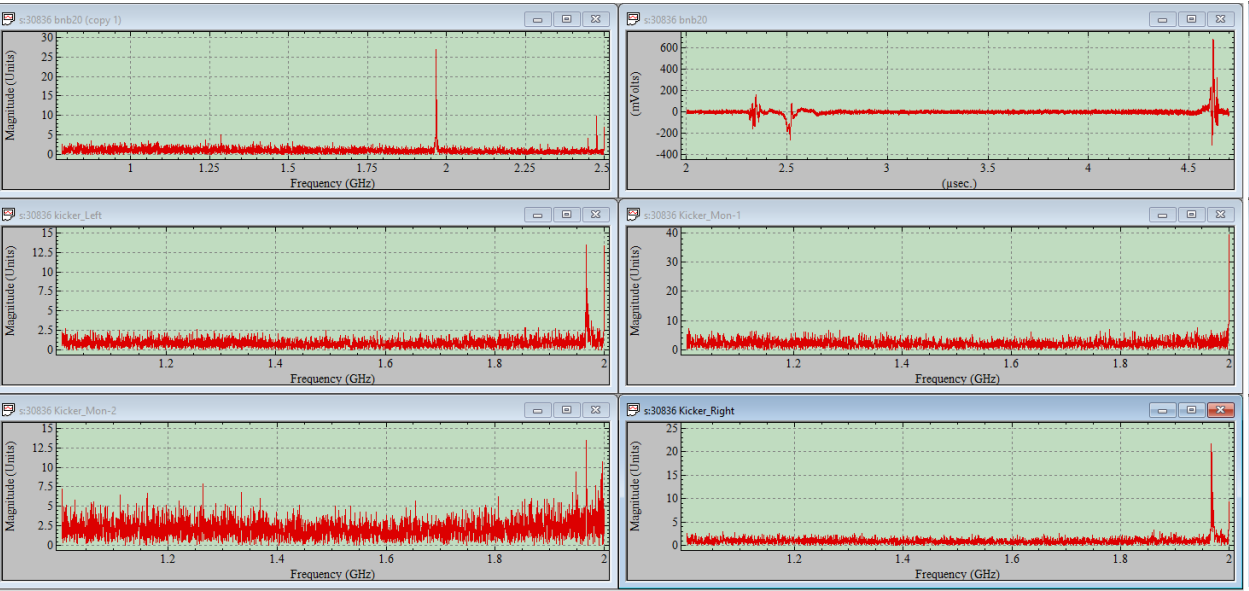
## 4011 (10-29-14)



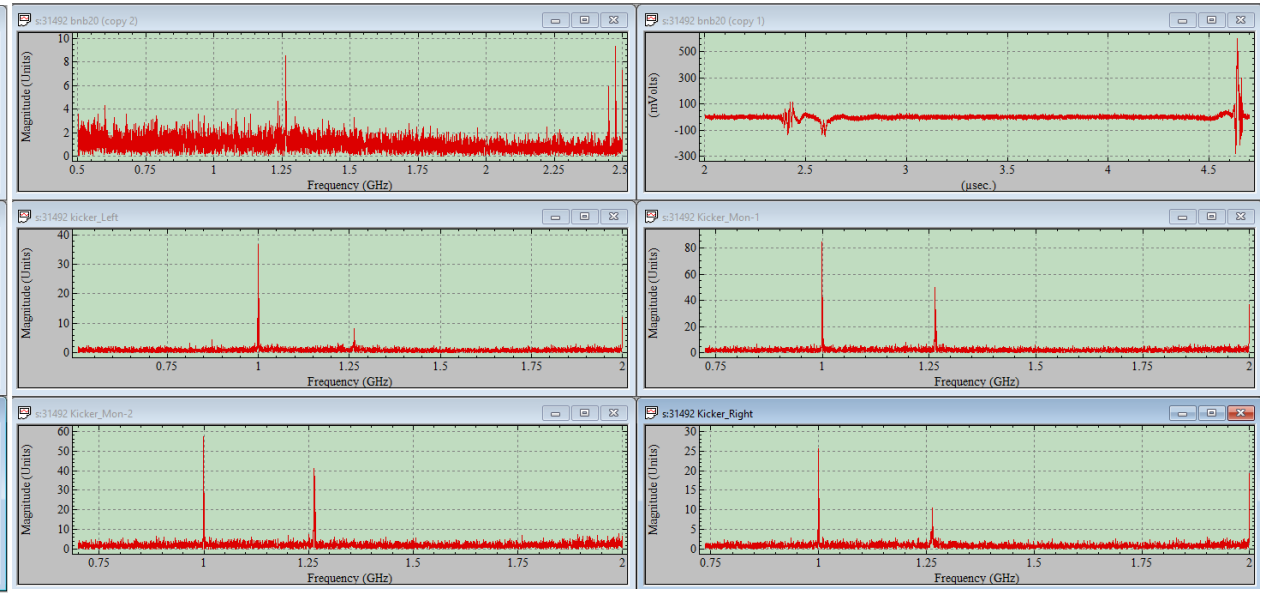

## 4013 (9-15-16)




## 3669 (11-30-16)

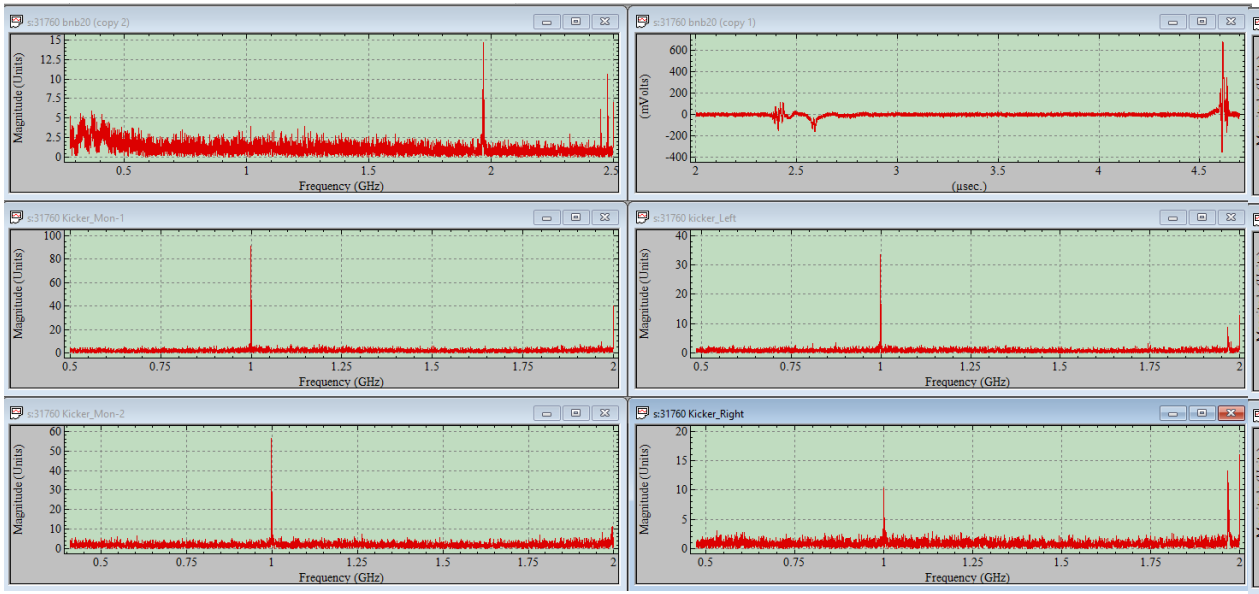



## H4472 (4-5-17)

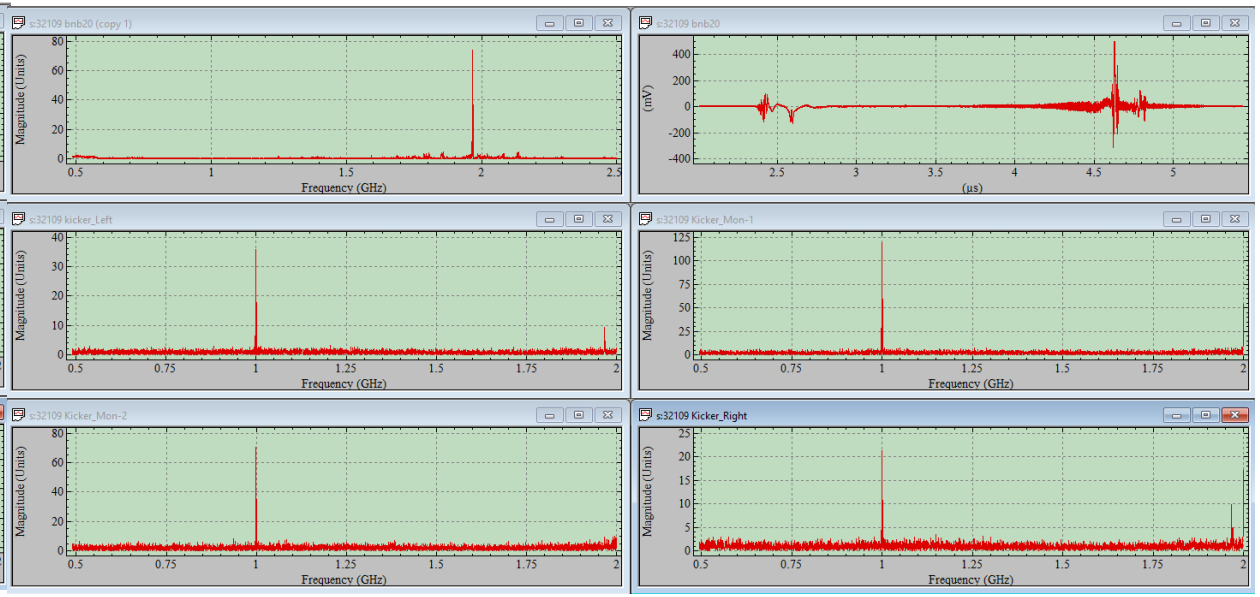


# Historical rf on hydros (post 5-17)

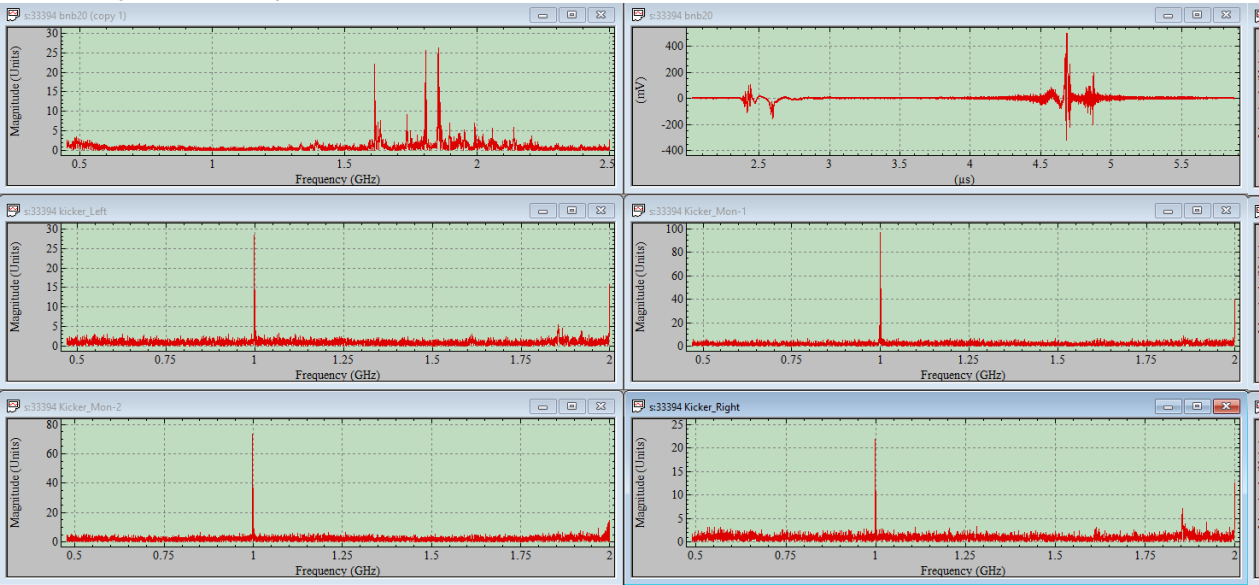
## 4015 (5-4-17) (Before BPM20 modification)



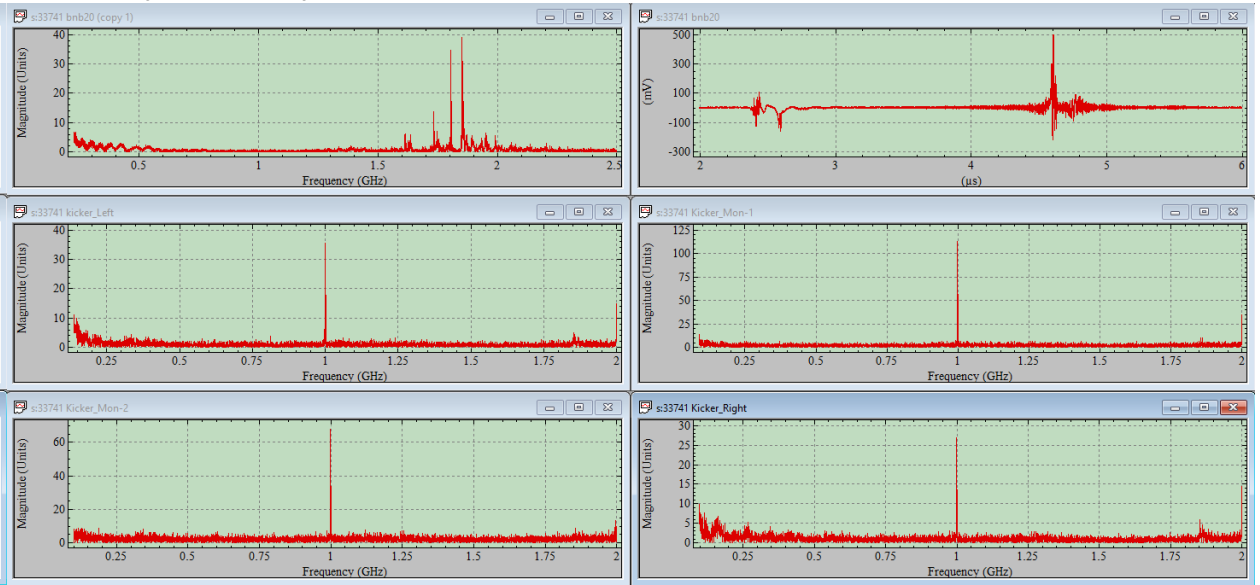

## 3671 (8-3-17) (After BPM20 modification)




## 3677 (3-28-18)



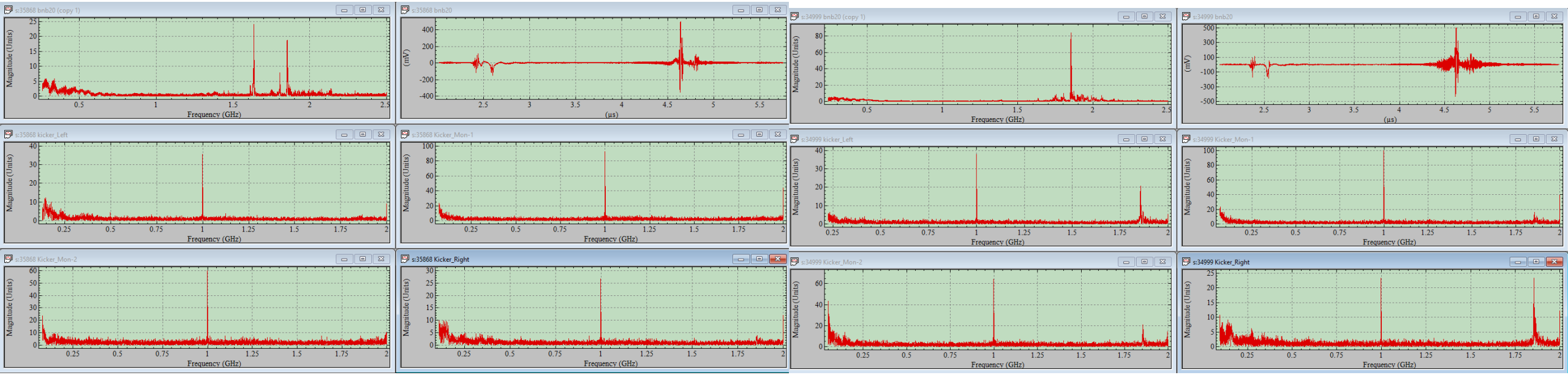

## 3682 (5-24-18)



# Historical rf on hydros

4019 (5-15-19)

3685 (12-13-18)



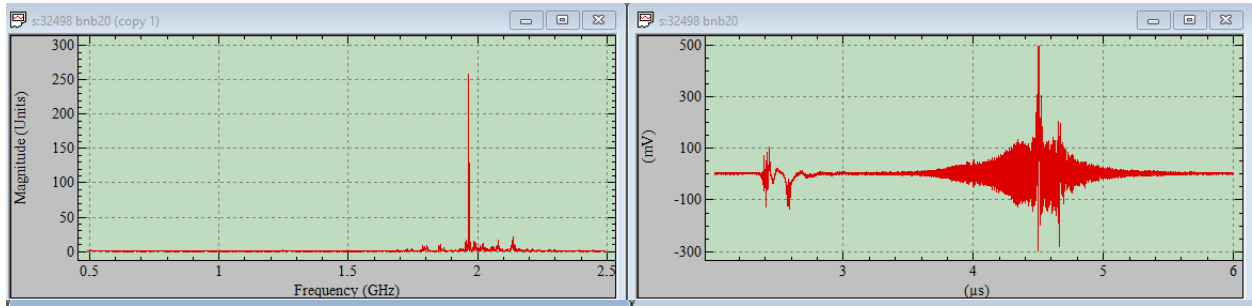

Last hydro – 4019 small rf on bnb20 - very little rf on kicker

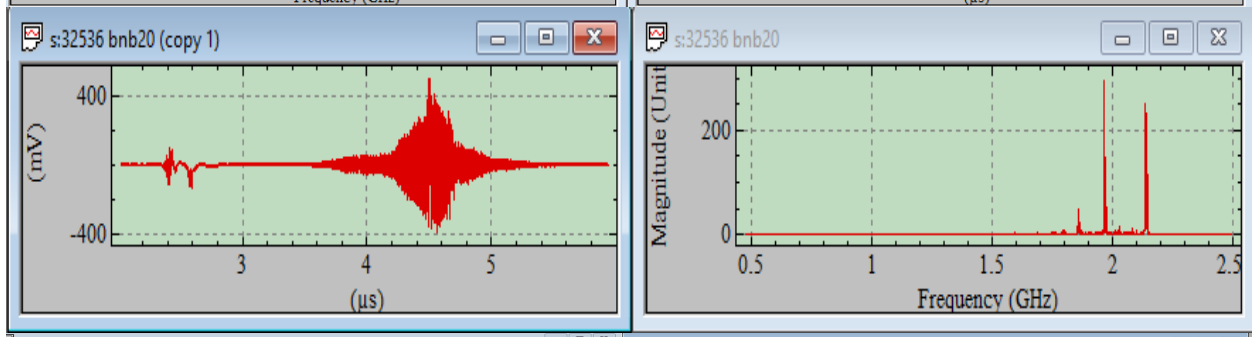
3685 – larger rf and more visible on kicker – predominantly at 1.84 GHz

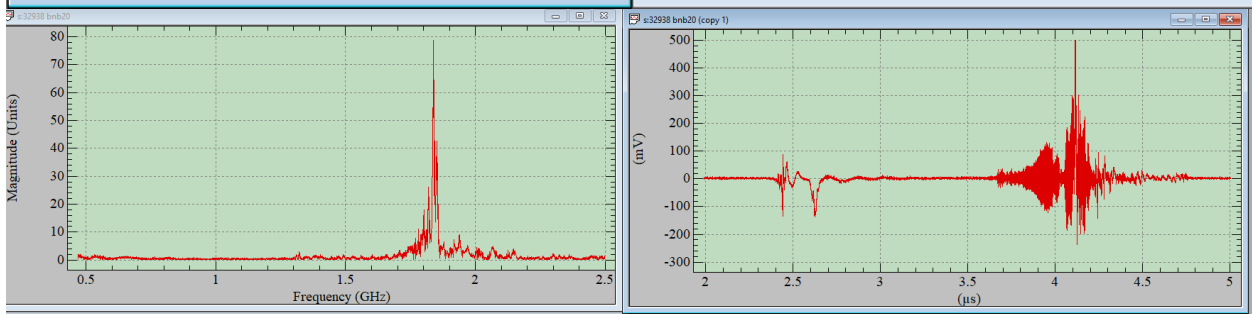
# All operations between 5-4-17 and 3-18-18

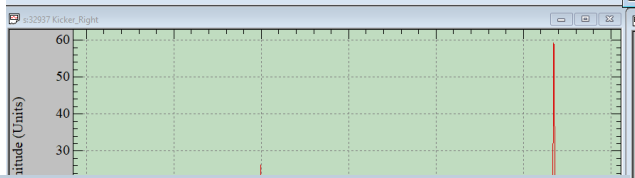
- 8-9-17 to 8-16-17 – target studies
  - On 8-9-17, the tune was based on 3671 and on 8-14 the tune was based on 3672 (10-19-16). These tunes have the same dose request.
  - No significant rf was observed on the kicker.
  - The rf on bnb20 was still dominated by a peak at 1.96 GHz on both days but the magnitude of the rf was almost a factor of 10 lower for 3672 as seen in Figure 12.
- 8-17-17 to 8-24-17 – Station C studies – short pulse – no rf
- 8-31-17 – single pulse target studies – short pulse – no rf
- 9-12-17 to 9-28-17 – target studies
  - **3671 tune – same rf as 3671 with some rf at 1.96 and 2.14 GHz depending on pulse format**.
- 10-23-17 to 11-13-17 –new cathode installed – Marx configured for short pulse **– Station A installed** – short pulse no rf
- 12-7-17 – Marx configured for long pulse – injector conditioning – Station A status unknown
  - **Long pulse – no rf in Mode 1**
- 12-11-17 to 12-14-17 – Station C – short pulse – no rf
- 1-18 – **New S2 magnet installed**
- 2-6-18 - First operations of 2018
  - **First evidence of substantial rf in Mode 1 - rf on kicker also – 1.84 GHz – S2 polarity wrong**
- 2-21-18 to 3-5-18 – Station C studies – mostly short pulse – no rf
  - **Shot 33149 with longer pulse shows rf at 1.96 GHz on bnb20 and kicker side electrodes as shown in Figure 14.**
- 3-7-18 to 3-13-18
  - Bnb20 shows rf at 1.96GHz on full pulse target shots with large shot to shot variations in intensity and occasionally no rf at 1.96 GHz
- 3-14-18 **Septum dump wedge removed**
- 3-15-18 – Target tuning
  - **Rf spectrum now resembles that of 3677 with no observable peak at 1.96 GHz.**
  - Kicker shows some rf on side electrodes and very little on upper and lower electrodes

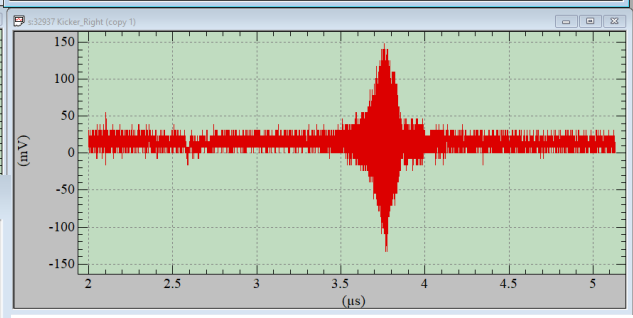
9-12-17 ➔ Mode 2 - strong rf on bnb20 at 1.96 with weak sidebands – tiny rf on kicker
9-13-17 ➔ Mode 2 - same
9-14-17 ➔ Mode 2 - same
9-25-17 ➔ Mode 2 - initially same – strong peaks added at 1.86 and 2.14 – little or no kicker rf
9-26-17 ➔ Mode 2 - Same with new peaks
12-7-17➔ Mode 1 - long pulse – no rf
2-6-18 ➔ Mode 1 – 1 us pulse – strong rf - new spectrum with resonance at 1.84 GHz –substantial beam shift and current increase on BPM21 – New S2 (wrong polarity)
3-7-18➔Mode 2 – long pulse – bnb20 strong rf at 1.96 with some on kicker – BPM20y position
3-8-18 ➔ same
3-12-18 ➔ same
3-13-18 ➔ no rf on some shots (cell timing)
3-15-18 ➔ New rf spectrum
3-19-18 ➔ same
3-21-18 ➔ same with 1.86 GHz more prominent

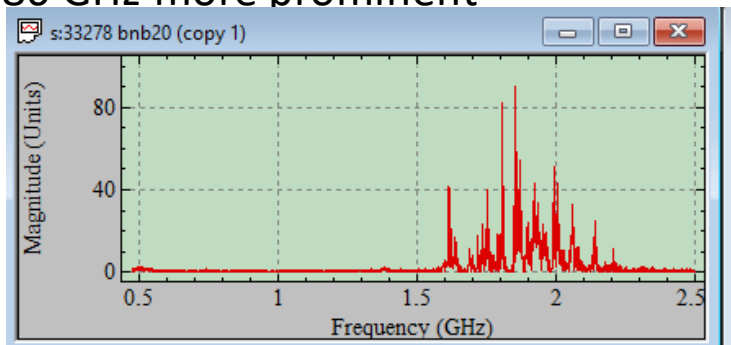


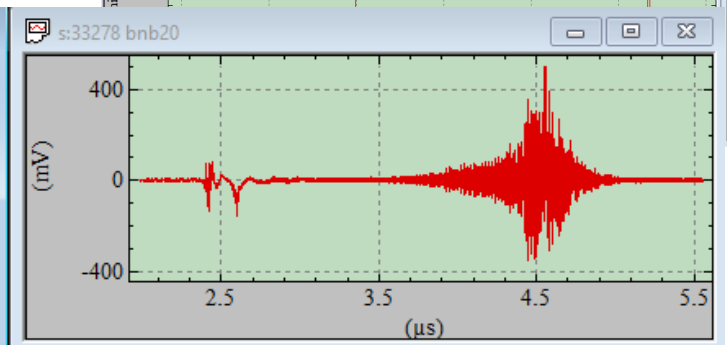



# What happened?

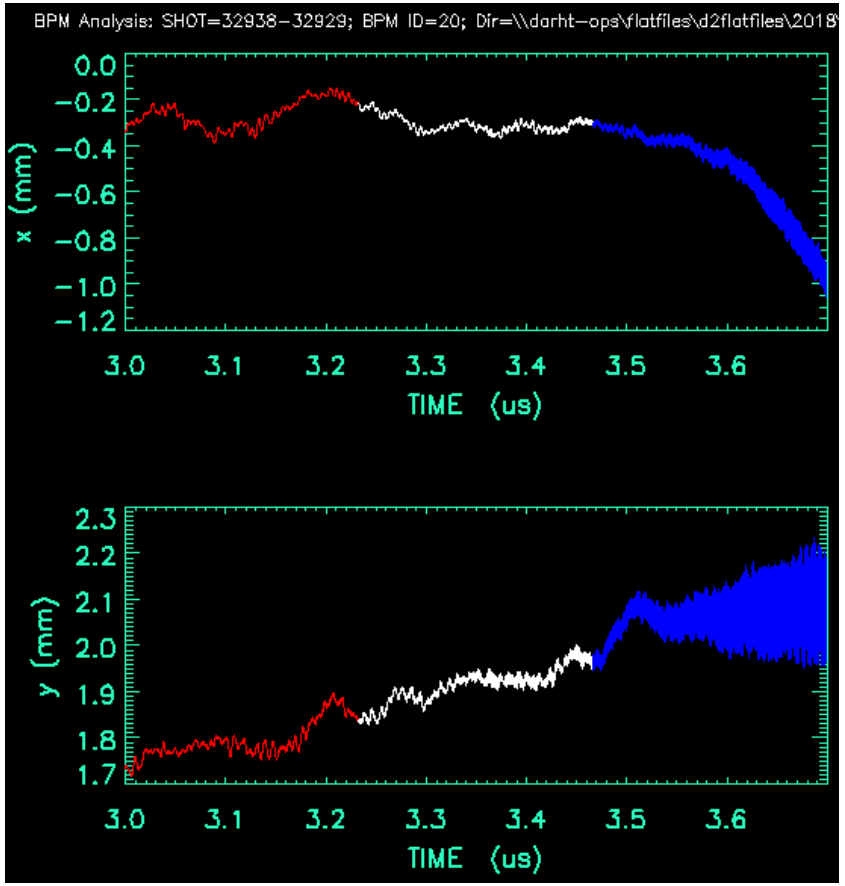
We made many changes in the Mode 1 DST and rf showed up!

- New digitizers
  - no real changes in rf except persistence after crowbar
  - Possibly greater sensitivity
- New S2 magnet and associated beam tube
  - Same tube diameter?
  - Exactly same location?
- Station A
  - New cross, screens (screens do form a box)
    - Differences from Mie configuration?

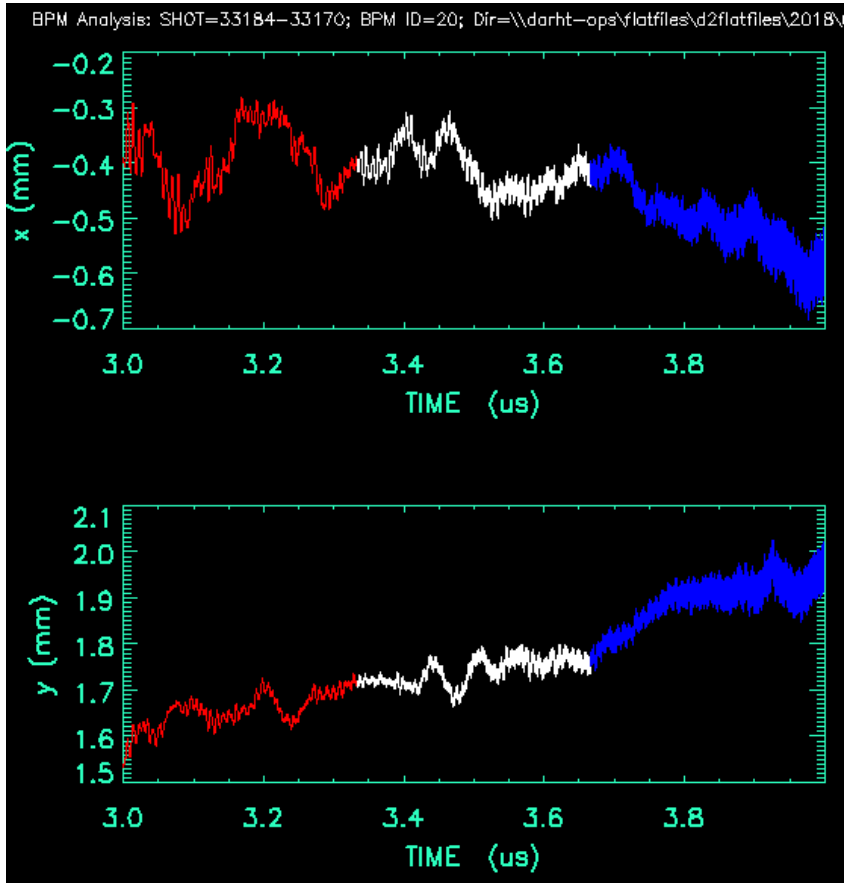
If no obvious solutions, suggest making deliberate changes in attempt to eliminate rf. Focus on Station A/S2 region.

# Examples of BBU on BPM20

2-6-18 – New S2 – wrong polarity – 1.2 us pulse
Mode 1

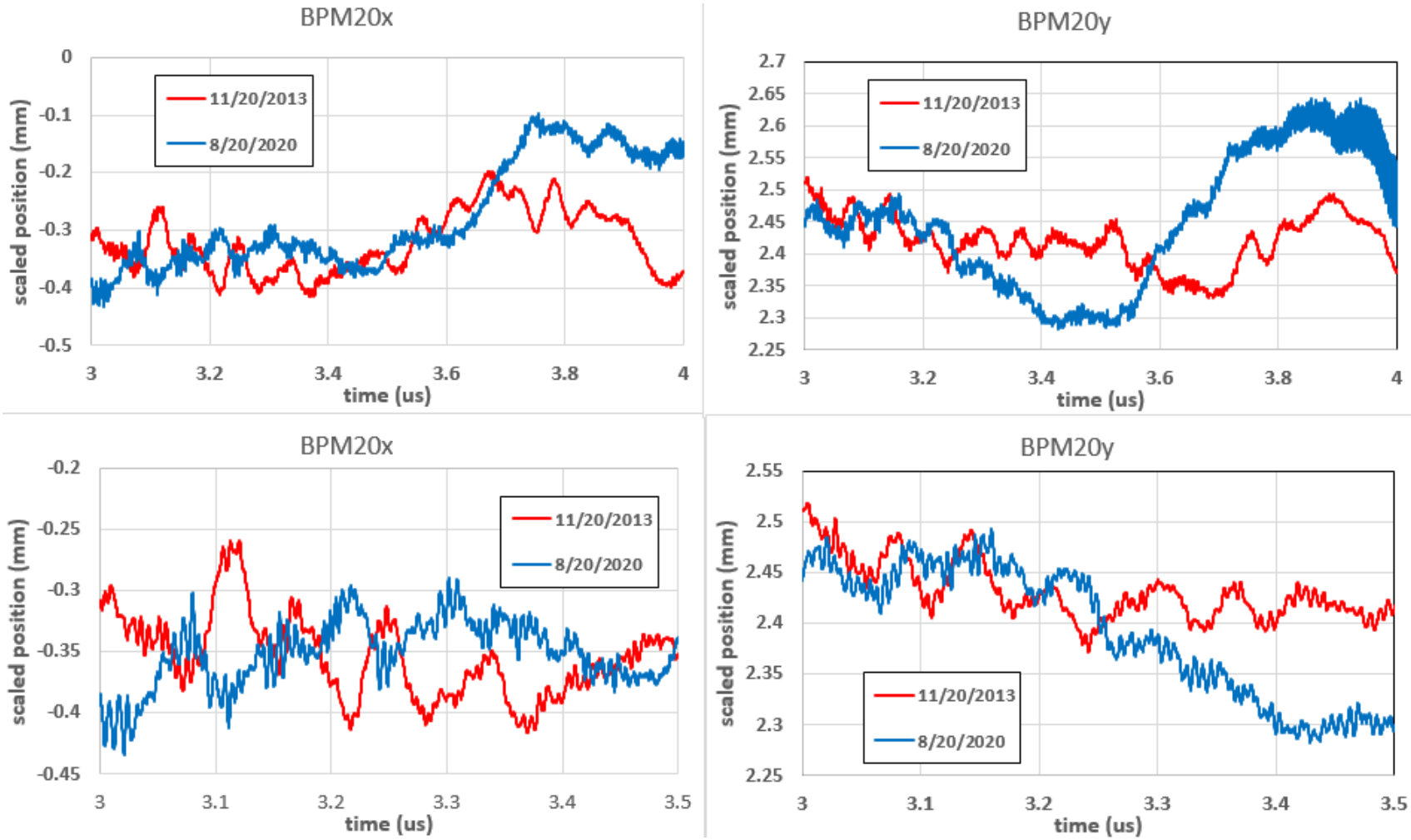



3-7-18 – target studies - Mode 2




Typical BBU presently seen is shown between 3.0 and 3.5 us
High frequency oscillations seen at later times are disturbing and occur on 10-20% of pulses

# Present BBU structure is 2x larger than prior accelerator tune



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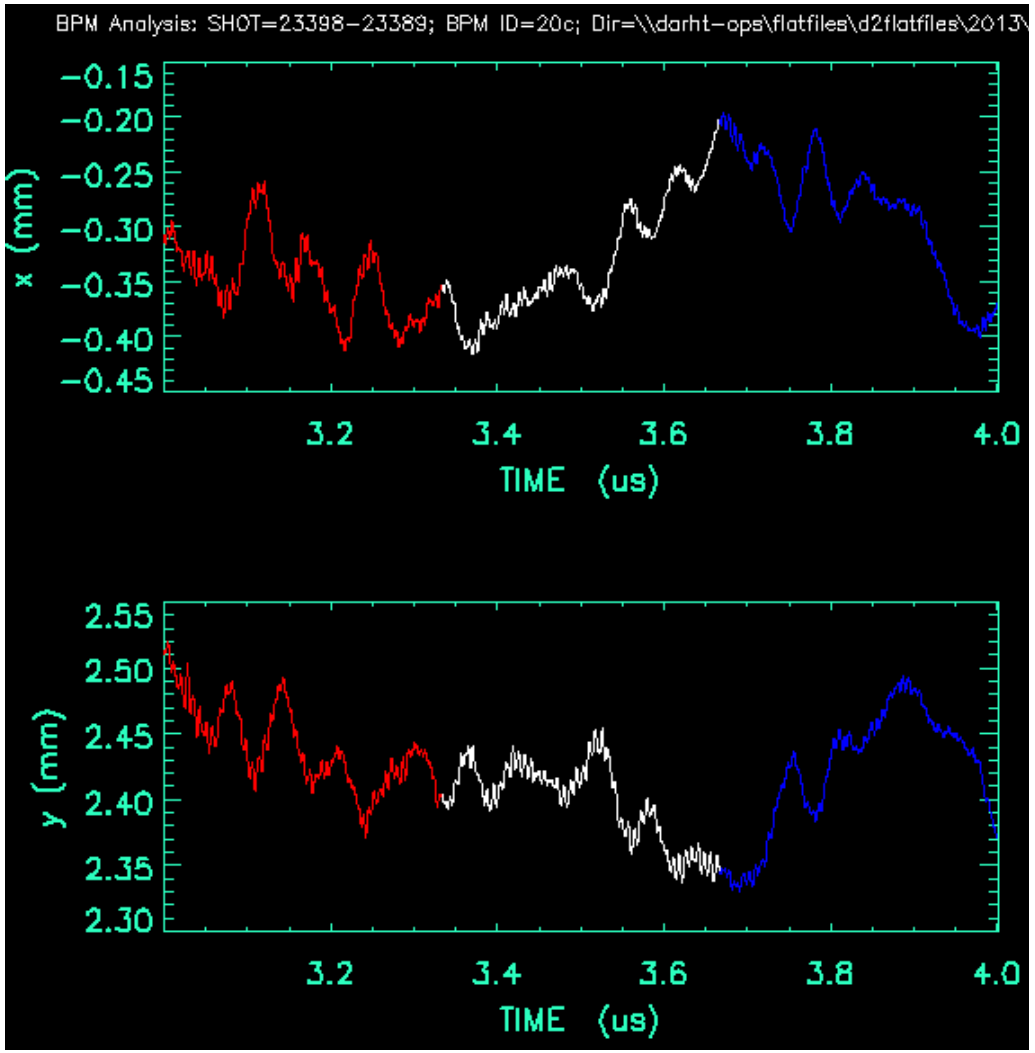
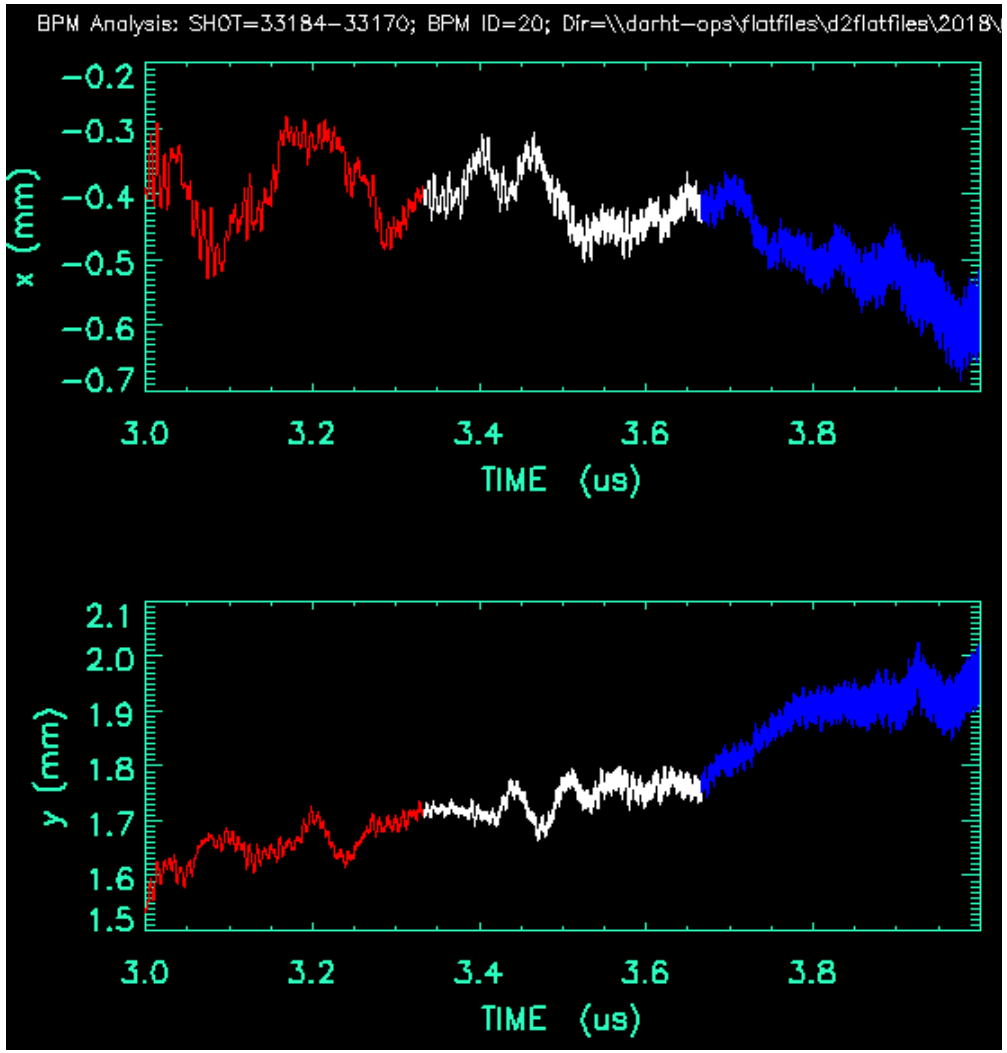
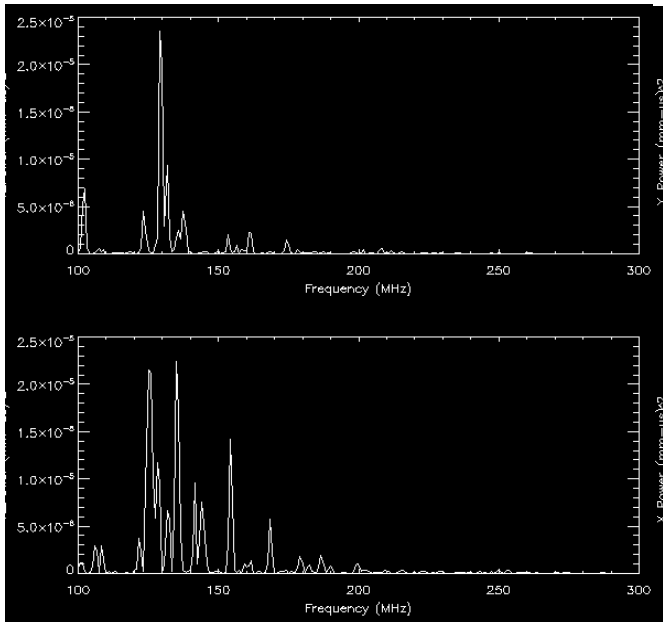


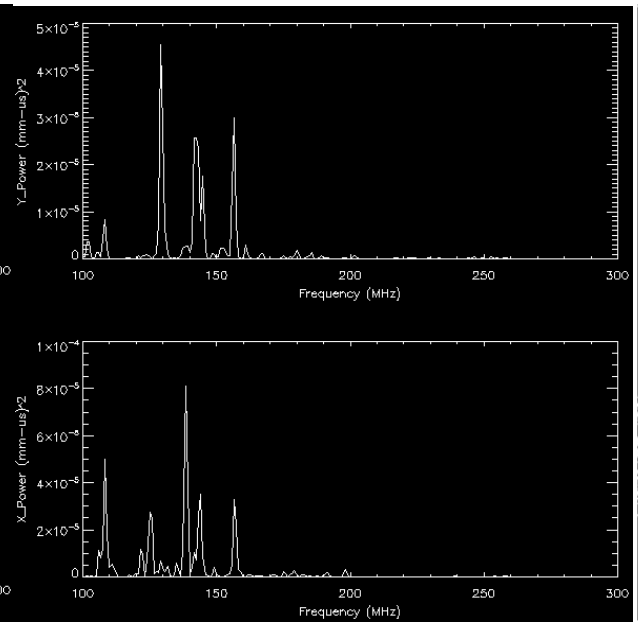



# Typical BBU Spectrum from D2_bdot

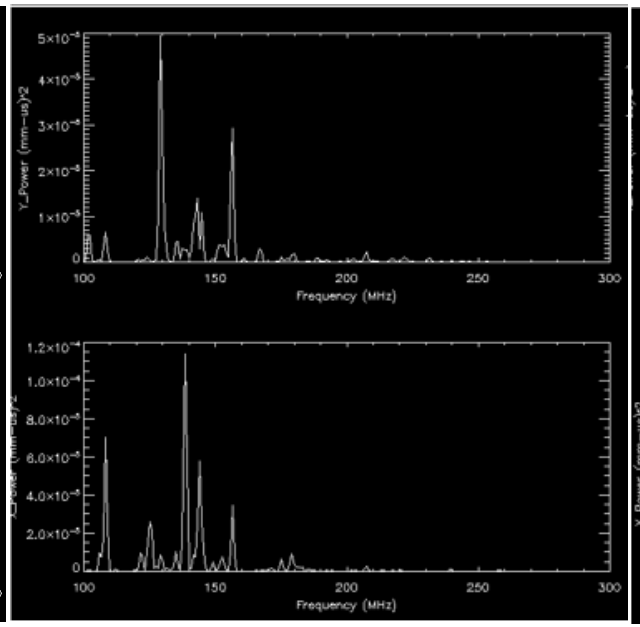
4019 (5-15-19)



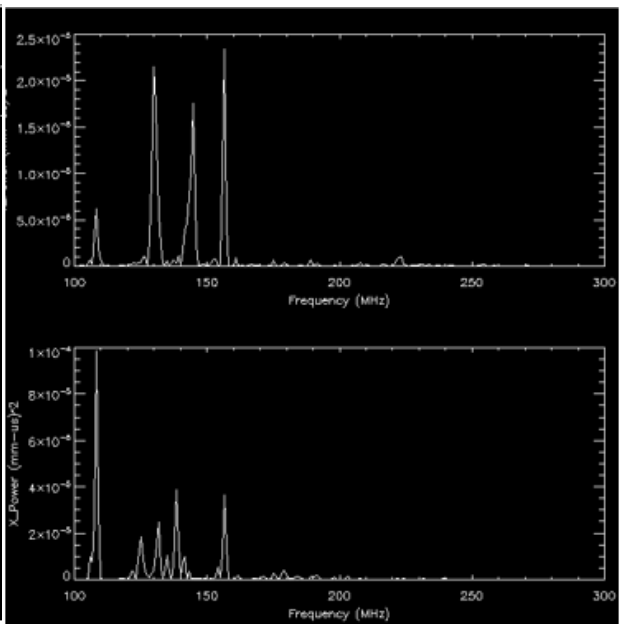

3666 (2-16-17)




3664 (2-4-16)

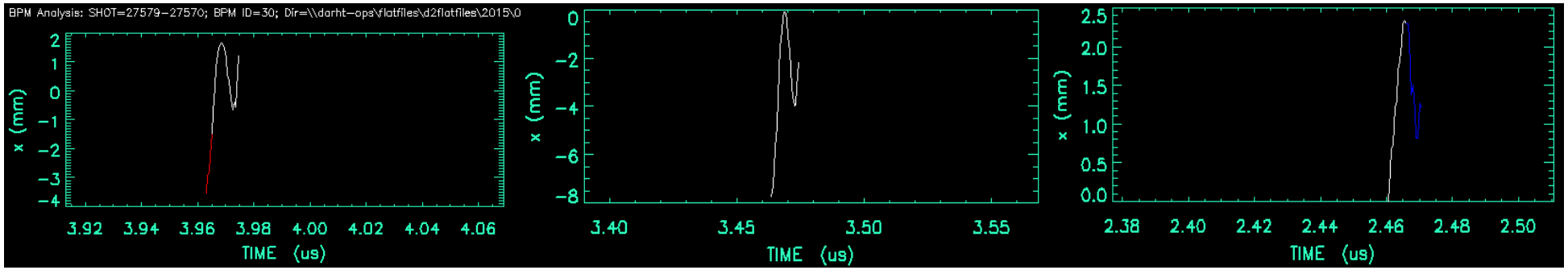



H4275 (4-15-15)

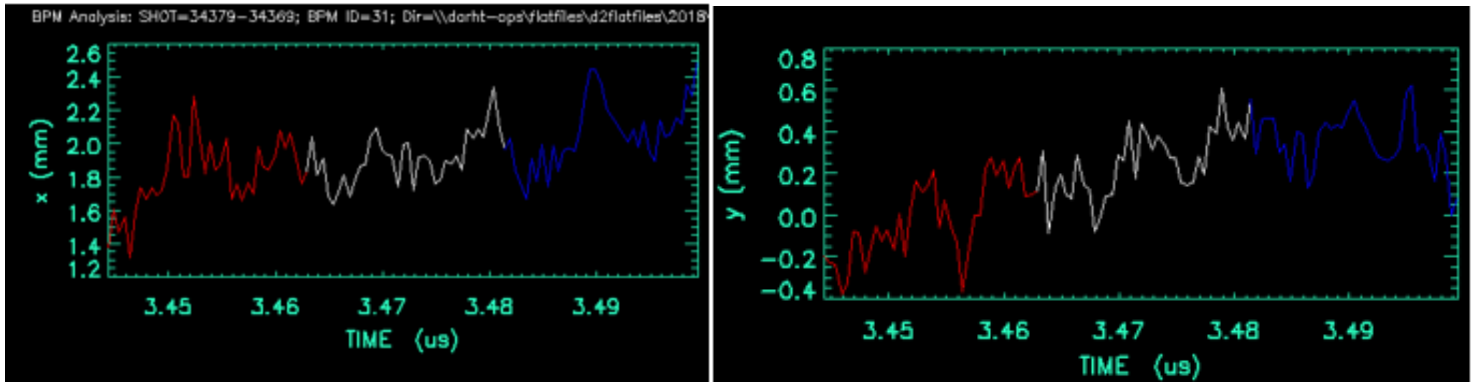



The most consistently strong peak is at 130 MHz corresponding to about 7.7 us

# 6-10 us structure is observed in BPM31 at the target that could contribute to the spot size

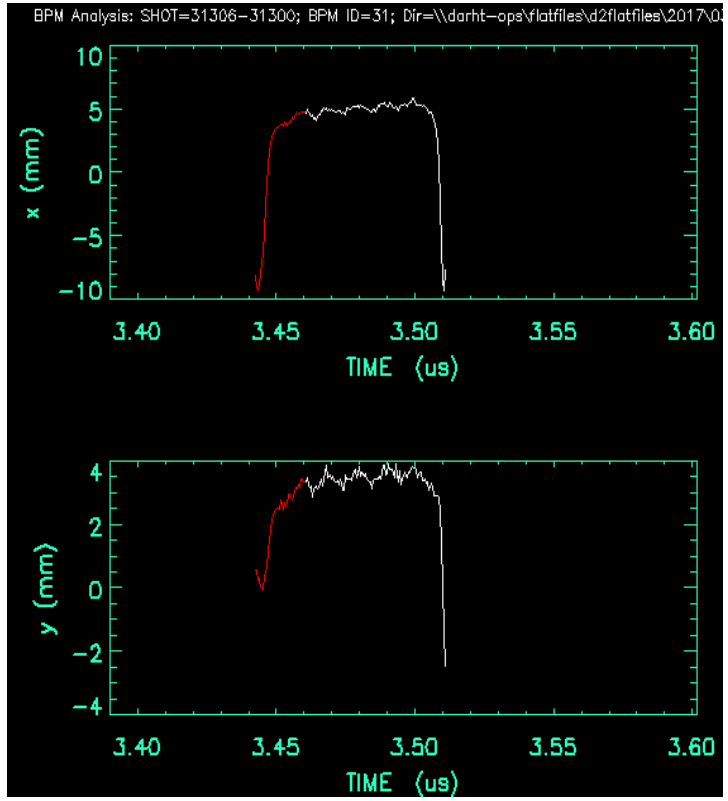



Hydro 3667 (7-10-15) – Fluctuations in the beam position at BPM30 for P2 (bottom), P3 (middle) and P4 (top). The fluctuations in the beam position are significant and have a period consistent with BBU

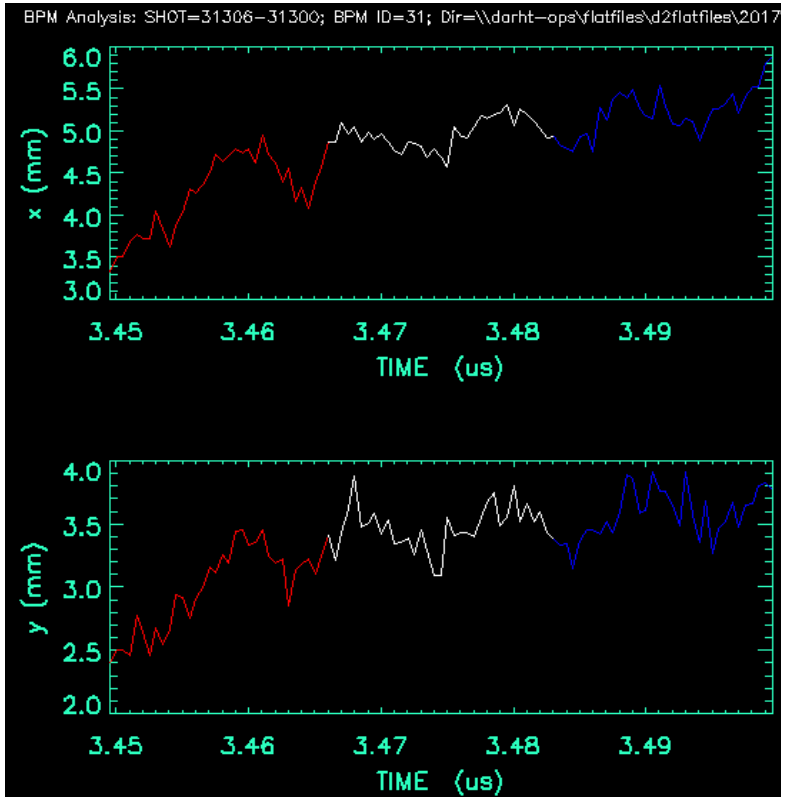



Hydro 3675 (8-29-18) – Expanded view of the fluctuations in the beam position at BPM31 on the beam flattop. The fluctuations have a period of 7-8 ns corresponding to BBU and most likely contribute to the spot size on target.

# 6-10 us structure is observed in BPM31 at the target that could contribute to the spot size




Hydro 3683 (3-15-17) – Beam position of P3 at BPM31. The right side shows an expanded view of the position fluctuations on flattop. The periodicity of the fluctuations is not as evident in BPM30 compared to BPM30 and is clearly consistent with BBU frequencies.



# Summary

- Source of Mode 1 high frequency (1.84 GHz) rf is not known
  - Not associated with Septum dump
  - Initial changes to Station A did not show rf in Mode 1
  - New S2 installation did correlate with Mode 1 rf
  - Station A screens form a box (when was target removed and screens modified?)
  - Need to make deliberate changes to see cause and effect
- BBU may contribute to spot size on target
  - Accelerator tune was changed in early 2014
    - Solenoid field was reduced in last few cell blocks resulting in reduced corkscrew and increased BBU
    - BBU increased by over a factor of 2
  - Create a new tune with stronger fields in last few cell blocks
  - Compare apples and apples with present tune
  - Both tunes require corkscrew minimization